TECHNICAL EXHIBIT FOR S-BAND AND X-BAND VIDEO RECEIVING SYSTEM

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TECHNICAL EXHIBIT FOR S-BAND AND X-BAND VIDEO RECEIVING SYSTEM

INTRODUCTION

A preliminary study directed toward a determination of the characteristics suitable for S-Band and X-Band crystal-video receiving systems useful for the detection of pulsed radiation at large distances from the signal source has been completed. It is the purpose of this Exhibit to present the results and recommendations arising from that study, and to indicate in a preliminary manner the configuration anticipated for the several units of the receiving system.

CHARACTERISTICS OF SIGNAL SOURCES

It has been assumed that S-Band radiation would arise from V-beam radars operating in the frequency band extending from 2700 to 3050 megacycles, and operating at a pulse repetition rate of approximately 340 pulses per second. The pulse width has been assumed to lie between 1.0 and 1.5 microseconds. It was assumed further that S-Band radars would be characterized by nominal power output of 1.0 megawatt and approximately 40 db antenna gain. Allowance was made, however, for 10 db temporary degradation in radar performance. Proper utilization of these factors indicates that the minimum probable power density at maximum significant distance from such radars will approximate a value of 20 microwatts per square foot.

Corresponding quantitative data for X-Band radars of interest is not available. It will be assumed, however, that search over the band extending from 8800 to 9800 megacycles may be accomplished readily, and that pulse repetition rates up to 2000 per second may be anticipated for AI radars, with corresponding values ranging from 320 to 3000 pulses per second for bombing radars. AI and bombing radar power outputs may be as low as 10 kw in some instances and are likely to be as high as 250 kw in other cases. Assuming radar antenna gains in the neighborhood of 30 db, it may be determined readily that incident power densities upon the receiving antenna may be expected to range from zero to 175 milliwatts per square foot. It should be noted, however, that the latter figure is an extremely unlikely one; more realistically, maximum power densities are likely to be several orders of magnitude lower than the figure indicated.

COMPONENTS OF THE CRYSTAL-VIDEO SYSTEM

The system to be developed consists of four basic components: These

are the antenna structures, the crystal detectors, the video amplifiers, and the magnetic tape recorder. Considerations relative to the operating environment of the system indicate the need for so designing the individual components as to minimize to the greatest extent possible the total system weight. An upper weight limit of 10 pounds has been selected as the design goal.

Basically, the system utilizes two antennas mounted back-to-back in a manner such that maximum antenna response is secured from radars whose line of sight to the receiving antenna is approximately normal to the longitudinal axis of the aircraft. Each antenna mounts a crystal detector and its associated video amplifier. Output signals from the two video amplifiers are conducted to the recorder, where separate records are made of the signals received on each of the two antennas.

The functions of the antenna are those of providing sufficient cross-section to insure reliable detection of S-Band radars at the maximum ranges of interest and to discriminate strongly against radars so located as to fall outside the beam of the receiving antenna.

Signals picked up by the antenna are delivered to the crystal detector unit where they are rectified to produce video pulse signals whose wave form is generally similar to the modulation envelope of the radar signal. The detector output signal is passed to a video amplifier where it is first amplified without significant waveform distortion and is then stretched in time duration to permit effective recording of the signal on a slow-speed magnetic tape recorder.

The recorder provides a driving mechanism, a set of recording, monitoring, and erase heads, and a supply of magnetic tape sufficient to permit continuous recording throughout a flight. The recording head structure should be such as to permit the recording of two independent information records simultaneously, and to provide a third track to accommodate timing signals.

A detailed discussion of the considerations underlying the selection of characteristics for each of the system components is provided in the paragraphs that follow.

RECEIVING ANTENNAS

A preliminary study made to determine the probable weight distribution among the several components of the crystal-video system suggests that it would be reasonable to allot between 50% and 60% of the total system weight to the magnetic tape recorder, and that approximately 30% of the weight could be assigned to the antennas and their associated crystal

detectors. Accordingly, an upper weight limit of 1.50 pounds may be assumed for each antenna. The problem of antenna design then becomes one of determining the nature of the antenna structure that will provide the most nearly ideal response and structural characteristics within the weight limit imposed.

Three types of antenna structure have been investigated. The first of these is the horn-type structure. It has the advantages of being comparatively easy to fabricate and is a relatively low-cost structure. Compared to the other antennas investigated, however, it has the disadvantage of being substantially heavier for a given quality of electrical performance and does not lend itself as readily to direct modification to permit change in operating frequency as the parabolic type of antenna. Preliminary calculations suggest that the best horn design would represent a compromise between weight limitations, pattern, and over-all length of the device. The horn flare angle determines in large measure the antenna side lobe pattern, and it may be determined readily that a flare angle in excess of 30 degrees is rather undesirable. A structure of possible interest for the present application would take the form of a horn having aperture dimensions of 9 inches x 4 inches, and a flare angle of 30 degrees. The over-all length of the antenna, including the section of waveguide in which the crystal is mounted, approximates 12 inches. The beam width of this horn in the H-plane is approximately 38 degrees; the antenna gain is about 13 db. If the antenna were cast in magnesium, its weight would lie in the vicinity of 0.7 pound, while an aluminum structure of identical dimensions would weigh about 1.0 pound. Although some reduction of beam width could be accomplished within the weight limit imposed upon the antenna structure, the over-all length of the unit would prove to be excessive.

The second form of antenna investigated was of helical design. The helix has the advantages of providing great bandwidth with low standing-wave ratio, of receiving plane or circularly polarized signals, and of providing narrow beam widths in relatively compact structures. Very narrow beam widths may be achieved by employing arrays of helical elements. Unfortunately, however, the helical antenna structure is difficult to fabricate in a form that provides a great rigidity, and it is uncertain what the effect of shielding produced by the aircraft skin would have on the antenna pattern. The latter factors rule strongly against further consideration of the helix at this time in view of the comparatively short development period available.

The third antenna structure investigated in considerable detail is the parabolic dish. The parabola appears to provide an excellent compromise between the most desirable characteristics of the helix and those of the horn. For a given weight, its beam width is appreciably less than that of the horn. It can be produced to exhibit adequate structural rigidity, and can be perforated readily to secure significant weight reduction. Its dipole antenna can be mounted to receive plane polarized signals in any plane desired, and its gain is generally comparable to that of the other structures

considered. The antenna pattern is relatively symmetrical, but the bandwidth of the antenna is less than that of either the helix or the horn. An antenna structure approximating 10 inches in diameter and an over-all length from dipole to the end of the crystal holder of about 5-1/2 inches would provide a beam width of approximately 24 degrees in the absence of aperture effects produced by the window in the aircraft skin.

Several other types of antennas, including the dielectric rod antenna and lens-type structures, were investigated briefly. For a given weight, the dielectric rod antenna can provide electrical characteristics generally comparable to those of the parabola; its length, however, would be of the order of three times that of the parabola, and its side lobe pattern would appear to be inferior to that of the parabolic antenna. With no significant advantages to recommend its use, further consideration of the rod antenna was dropped.

Lens-type structures were given brief consideration because of the possibility of utilizing such structures to provide uniform illumination for the aperture of a horn, thereby in turn permitting a somewhat wider flare angle to be employed in horn design. The combined weight of lens plus horn, however, is significantly greater than that of the simple horn structure, and no significant justification for further consideration of this comparatively complex form of antenna could be found.

In summary, the helical antenna would appear to provide a structure capable of yielding the most nearly optimum antenna pattern for a given weight; it would be difficult, however, to produce the helix in the form of a rigid structure and to insure that modifications of the antenna pattern resulting from induced currents on the aircraft skin could be compensated adequately within the period available for equipment development. Accordingly, it is proposed to concentrate effort in the immediate future upon a detailed study of the characteristics of horn and parabolic type antennas, the indications at this time pointing strongly toward eventual selection of the parabolic form for production units.

Because each antenna will view the terrain on one side of the aircraft through a laminated plastic and fiberglass window approximately 12 inches x 12 inches in size, it will be essential to have a partial mock-up made of that portion of the aircraft nose structure containing the window, so that antenna pattern measurements can be made under conditions simulating closely those under which the antennas will be operated.

The antennas employed for X-Band operation will differ from those provided for S-band operation principally in the size scale of the structures, unless further study of the system suggests the desirability of response pattern modification.

CRYSTAL DETECTORS AND VIDEO AMPLIFIERS

The crystal detector associated with horn-type antennas will be mounted in a section of waveguide attached to the end of the horn; the detectors of parabolic antennas will be mounted on an extension of the coaxial feed line extending a short distance behind the dish. Crystals of the 1 N32 type, or generally equivalent units, will be employed in suitable mounts in a manner such as to provide negative-going pulse outputs when the antenna is excited by radar signals. The detector output signals will be delivered to an amplifier utilizing direct-coupled feedback pairs to provide the gain required at video frequency; the output signal of the video amplifier will then be delivered to a pulse-stretcher circuit to increase the time duration of individual pulses to a value that will permit pulse recording on a slow-speed tape recorder.

Design of the amplifiers will be such as to provide a dynamic range essentially equal to that available from the magnetic tape record. A final decision concerning the type of tape to be employed cannot be reached until experimental data for certain special types of tape has been secured; nevertheless, it is anticipated that the tape recorder will provide a useful dynamic range in the vicinity of 35 db.

Two amplifier configurations have been investigated, and preliminary laboratory work on both is underway to permit detailed evaluation of their advantages and disadvantages. Both of these amplifiers employ subminiature vacuum tubes and will utilize circuit components designed to operate reliably at temperatures as low as -65° C. Output signals from the video amplifiers will be delivered to the recorder over a coaxial transmission line.

Transistorized video amplifiers are being investigated also. It is probable that such units can provide the electrical performance desired in a somewhat smaller and lighter package than would be required for tube-type amplifiers, and the utilization of junction-type transistors would essentially eliminate microphonic problems in the amplifier. Power for transistor amplifiers could readily be provided by a compact and lightweight battery source associated with each amplifier, thus eliminating the need for power-supply cables to the video amplifier. However, it is presently contemplated that the antenna-detector-amplifier units will be located in an unpressurized and unheated section of the airplane nose, and it is doubtful whether adequate transistor performance can be secured at the temperatures that are likely to prevail in this portion of the airplane, and it is almost certain that batteries capable of providing useful output at the low temperatures that will be experienced are not available at this time. The several points in question will be investigated, however, to permit an adequate decision with respect to amplifier structure in terms of the best information available at this time.

Little thought has been given as yet to the form of amplifier structure that will be employed. Nevertheless, it is reasonably probable that etched wiring of the amplifier units will be employed; the etching techniques contemplated for this application provide for the formation of plated-through eyelets in the component mounting holes of the etched board, this feature being stressed because of difficulties that have been experienced with etched wiring in which this technique was not employed.

The amplifier units developed for X-Band operation will differ from those provided for S-Band operation principally in that the former units will be designed to amplify and to stretch suitably the shorter duration pulses characteristic of X-Band operations.

RECORDERS

Initial information provided to this contractor indicated that a total recording time of approximately seven hours without recorder reload would be required, and recorder design has proceeded thus far on this basis. Recent discussions with representatives of the contracting agency have indicated, however, that a total recording time approximating 8-1/2 hours more nearly meets the actual requirements, and modifications to the recorder design are being investigated to meet this requirement.

Because the recorder will be the heaviest unit of the system being designed, great emphasis has been placed upon the development of a unit which would yield maximum performance in a structure of minimum size and weight. The design presently under development provides a recorder base structure which houses the three motors required for tape drive, take-up drive, and supply-reel braking, worm-gear speed reduction mechanisms, tape-drive filter, erase and recording heads, and a set of reproducing heads which, in conjunction with an associated set of transistorized amplifiers, permits direct monitoring of the signals recorded on the three tracks provided on the tape record. A magazine-type structure, containing supply and take-up reels in a coaxial configuration, together with the tape channel guiding mechanism, is designed to mount directly on the recorder base in a manner such as to avoid the need for manual tape threading and positioning. The tape would be driven at a speed of approximately 1-7/8 inches per second.

Because the magazine and its tape load would constitute a significant portion of the total recorder weight, an investigation has been undertaken to determine the feasibility of securing magnetic coating upon an unusually thin tape base, particular emphasis having been directed toward securing coatings on 0.5 mil Mylar. A sample load of this Mylar tape was delivered to the contractor on 21 February 1955, and it will be tested immediately to determine whether print-through signals from layer to layer of the roll exhibit an amplitude in excess of the tape background noise value. Should it

be determined that print-through is not a problem, it is likely that an adequate tape supply for 8-1/2-hour recordings can be carried on 10-1/2-inch reels. On the other hand, if significant values of print-through signals are found, 0.5 mil Mylar must be ruled out for this application, and a 1.0 mil base material must be employed. In the latter case, it is doubtful whether it will be possible to provide for 8-1/2 hours recording on a single tape load without necessitating the use of a magazine structure of inadequate rigidity for field usage, and it will be necessary to investigate various alternative approaches to the problem of providing adequate recording capacity.

Accurate speed regulation is required on the tape-drive motor. Two approaches to providing such regulation are under investigation. The first of these contemplates the use of a centrifugal-type contact-making governor; the second is based upon the utilization of power-type transistors in conjunction with a bridge structure to regulate speed by maintaining constant the frequency of a signal developed by a tone wheel mounted on the motor shaft.

Several types of motors have been ordered from motor manufacturers to permit evaluation of their suitability for the present application. Each of the types requested is very highly miniaturized, yet provides substantially more torque than that required for satisfactory recorder operation. None of the companies contacted is currently in production on a governor of the kind required for this application, and it is probable that the contractor will find it necessary to undertake directly the development of a suitable device of this kind.

The recorder will employ magnetic tape one-quarter inch in width, upon which there will be produced three record tracks. Each track will be 0.045 inch in width, and the tracks will be separated by guard areas of equal width. With the tape running at a speed of 1-7/8 inches per second, reasonably uniform response should be obtained up to a frequency of 2000 cycles per second.

Production of three tracks in parallel on one-quarter inch tape will necessitate the development of special and highly miniaturized recording heads. Specifications have already been given to a local producer of such devices, and it is anticipated that two sets of such heads will be delivered for experimental evaluation in the near future. These heads will employ gaps approximately 0.00025 inch in length. Essentially identical reading heads will be mounted in the recorder to permit immediate reading of the recorded material for the purpose of ascertaining whether proper recorder operation is being secured. The output of the reading heads will be amplified suitably by three transistorized amplifiers mounted in the recorder base. An erase head, energized by a transistor oscillator mounted in the recorder base, will apply continuous erasing signal to the tape prior to its passage under the recording heads to insure the absence of undesired signals on the tape.

The achievement of uniform flutter-free tape motion will necessitate the development of precision worm-gear sets for motor speed reduction. Sources for the production of suitable gear trains are presently under investigation.

Each of the outer tracks on the tape will be employed to record received signals. The center track will be utilized for the recording of timing signals. It is understood that these may be developed from a clock in the airplane, in which case the clock output pulses will be utilized to gate the output of a transistor oscillator mounted in the recorder base in a manner such as to provide suitable timing signals to the center-track recording head.

It is contemplated that the recorders may be employed on the ground for transcription of the records produced by these units. In such applications, both the erase and recording heads will be omitted, and the signals produced by the reading head amplifiers will be modified suitably to permit re-recording of the record on tape recorders utilizing standard 35 mm. magnetic tape. This contractor will investigate the characteristics of several high quality tape recorders available on the open market and select a model best suited for transcription record production. Such modifications as may be necessary to the amplifier and recording head structures of the recorder selected for this purpose will be engineered by this contractor.

TEST EQUIPMENT

Proper performance of the crystal-video system in the field can be insured only if test equipment adequate to determine the over-all performance of the system and that of its several components is available. Such test equipment could be assembled from standard test equipment items now available from producers of such equipment, and repackaged to provide a test unit adequate for this application. It is probable, however, that this procedure would lead to the provision of test equipment far more versatile in its capabilities, and hence more likely to be misused, than the requirements for adequate test of the system under development would warrant. Accordingly, this contractor is proceeding with the analysis and design of special test equipment intended to produce only signals of the type required for adequate tests of the crystal-video system.

Four types of test signal are required. The first of these consists of an S-Band signal pulsed at a repetition rate of approximately 340 pulses per second, providing pulse widths in the vicinity of 1.25 microseconds, and employing a carrier frequency roughly centered in the band of interest. The second test signal would differ from the first primarily in that it would be located in the center of that portion of the X-Band of interest. The third form of test signal would consist of video pulses having a time duration of

approximately 1.25 microseconds, and available at selected repetition rates lying between 340 and 3000 pulses per second. The fourth type of test signal would consist of audio pulses having a pulse duration in the vicinity of 250 microseconds, and available at repetition rates equal to those provided for the video pulses.

Utilization of the pulsed S-Band or X-Band signals would permit direct tests on the over-all performance of all components of the system in a single operation. The individual video and audio pulse trains would be utilized to isolate difficulties present in the video amplifiers or in the recording circuits.

This test equipment would include only such controls and meters as were essential for use of the test equipment, thus simplifying the structure and operation of the equipment to the maximum degree possible.